Oxygen Microbubbles for In Situ Bioremediation of Petroleum Hydrocarbons

A Collaborative Effort between the US Air Force Research Laboratory (AFRL/MLQ), the US EPA SITE Program, and Industry

THE PROBLEM:

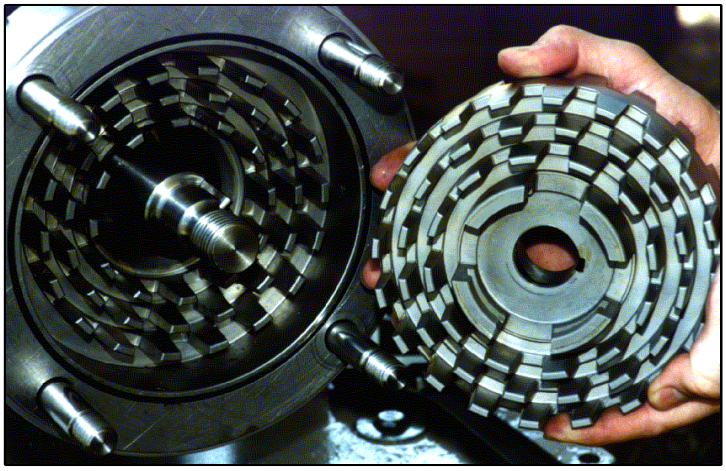
Aerobic biodegradation is effective for remediating petroleum hydrocarbons. However, optimization of biodegradation rates in the subsurface is limited by the availability of O_2. Air sparging and H_2O_2 application have been used to supply O_2 to groundwater, but these have limitations. In addition, iron precipitation problems associated with these techniques have not been overcome, limiting the ability to disperse O_2 throughout the area of subsurface contamination.

THE SOLUTION:

The in situ application of the O_2 microbubble technology for bioremediation of petroleum hydrocarbon contamination is a method thought to be more efficient and cheaper than H_2O_2. The process is designed for in situ bioremediation in the saturated zone and uses colloidal gas aphrons, a stable emulsion of air in water. Lab and pilot-scale experiments have demonstrated much higher O_2 concentrations in groundwater down gradient from the “aphron zone” than is achievable by air sparging or H_2O_2.

ENGINEERING DEVELOPMENT:

The O_2 microbubble technology uses a continuously generated stream of O_2 and a water solution containing low concentrations of a biodegradable surfactant. The water stream, containing approximately 200 mg/L of surfactant, is mixed with O_2 under pressure. The resulting mixture is pumped through a microbubble generator that produces a zone of high energy mixing.



Aphron Generator Mixer

The result is a 60 to 80 percent by volume dispersion of bubbles with a typical bubble diameter ranging from 50 to 100 microns. The microbubble dispersion is then pumped through an injection well into the treatment zone, supplying a higher mass loading of O_2 to the groundwater. When the aphrons are injected into the subsurface, they are caught up in the surrounding soil. Water, passing through the "aphron zone," acquires dissolved O_2 from the microbubbles. Aphrons remain in the saturated soil matrix for extended periods of time, allowing continued O_2 transfer to groundwater.

Colloidal Gas Aphrons

IMPLEMENTATION:

In July 1995, the first field pilot test of the aphron technology was performed at Tyndall AFB, FL. The objective was to determine, on a preliminary basis, how microbubbles perform once injected into a surficial aquifer. The effort was part of the US EPA Superfund Innovative Technology Evaluation (SITE) Emerging Technology program, implemented by OHM and supported by AFRL/MLQ and Tyndall AFB. The pilot test was performed in an uncontaminated area and revealed, through use of a helium tracer, that O_2 was transported in the saturated zone for a significant distance. Results were verified through analysis for the surfactant.

Building on the success of the July 1995 study, the same team initiated a larger field study in September 1996. The study was performed in a petroleum hydrocarbon groundwater plume on Tyndall AFB, FL. Six probes, installed in a hexagonal arrangement in the test area, served as injection points for the aphrons. Soil gas and groundwater was monitored for biological and chemical parameters such as tracer analysis, O_2, CO_2, temperature, BTEX, and dissolved O_2. Field efforts continued for ten months. Information on the results of the fielded system is available.

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